THE
DESCRIPTION and USE
OF A COMPLETE
SETT or CASE
OF
POCKET-INSTRUMENTS:
CONTAINING THE
CONSTRUCTION of the ſeveral LINES
LAID DOWN ON THE
PLAIN-SCALE, and SECTOR;
WITH THEIR
APPLICATION,
IN VARIETY OF
MATHEMATICAL PROBLEMS.

BY
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The SECOND EDITION, Corrected.

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PREFACE.

THE *following ſheets were firſt printed as an Appendix to* A compendious courſe of practical mathematicks, *which I publiſhed ſome time ago, and contain, as is ſet forth in the title,* The deſcription and uſe of a complete ſett or caſe of pocket-inſtruments. *Ever ſince that publication, I have been much urged to print the ſaid* Appendix *ſeparately, as a thing that wou'd be more generally uſeful: I have at laſt complied, and wiſh it may prove as acceptable to the Publick, as ſome private friends would perſuade me it will be.*

Something

PREFACE.

Something of this nature will certainly be neceſſary to all ſuch who furniſh themſelves with ſuch an Apparatus; *and I am apt to believe, that what I have herein delivered will be ſufficient for the purpoſe.*

For the ready turning to any particular, I have prefix'd a Table of Contents, *and therefore think it needleſs to add any thing farther by way of Preface, to a tract ſo ſhort, yet, I hope, clear and intelligible.*

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THE

DESCRIPTION and USE

Of a Complete

SETT or CASE

OF

POCKET-INSTRUMENTS.

A Complete ſett of pocket-inſtruments (though ſometimes made according to particular direction) generally conſiſts of the following particulars, *viz.*

I. A large pair of compaſſes, with one point made to take out, in order to receive in its place, either a drawing-pen, a port-crayon, or a dotting-wheel; according as you would deſcribe your circles or arches, with ink, black-lead, *&c.* or only with dots.

II. A ſmaller pair of compaſſes, for the exact taking of diſtances, or ſtriking obſcure arches, *&c.* in working geometrical problems.

III. A longer drawing-pen, whoſe handle contains a protracting pin, and a ſocket to hold a pencil.

IV. A parallel ruler.

V. A protractor, either ſemicircular, or (as they are more commonly fitted up for caſes) in form of a parallelogram or long ſquare, for the conveniency of laying down on the back ſide thereof, ſeveral lines of equal parts, both ſimply and diagonally divided, with two or three lines of chords of different radius's; and ſometimes all the ſeveral lines of the common plain ſcale are laid down thereon.

VI. A ſector.

Theſe caſes of inſtruments are made of ſeveral ſizes; but moſt commonly either of the length of four inches, four inches and a half, or ſix inches; which laſt ſize, though ſomewhat heavier for the pocket, are much more preferable in uſe, as the diviſions upon the ſector are more ſenſible, and conſequently their application in practice more exact.

Of

Of the Compaſſes.

A Pair of compaſſes is a thing ſo well known, that it would be little leſs than ridiculous to waſte words in its deſcription; but a few hints of direction, in judging of their goodneſs, may probably be of ſervice. Obſerve therefore, 1. That the motion of the head be equal; that is, that in opening or ſhutting you find no ſudden jerks or leapings. 2. That the joints are well fitted, ſo that there be no ſhake in the application of any of the points. 3. That they be well filed and poliſhed. And, laſtly, That the ſteel points are cloſe join'd, equal, and well tempered.

The uſe of a pair of compaſſes is as well known as their form; I have therefore little to ſay under this head, but that it is an inſtrument well adapted to the taking of diſtances, and deſcribing circles, or arches, from a given centre; which, as before was intimated, may be done either obſcurely, with the ſteel point; in ink, with the drawing pen point; in black lead, *&c.* with the crayon point; or by dots only, with the dotting wheel point; as the occaſion requires. Note, alſo, either of theſe points may be uſed to draw a ſtrait line along the edge of a ruler.

Of the longer drawing Pen, with the protracting Pin.

THIS inſtrument is compoſed of two ſteel blades, fixed into a ſmall pillar of braſs, ſilver, *&c.* one of which, by means of a joint, may be made to open for the conveniency of cleaning; and by help of a little ſcrew, they are eaſily ſet to the proper thickneſs of the line you would draw; the ink being inſerted into the cavity betwixt the blades, with a pen; ſo that if the blades are well fitted and poliſhed, the line they draw will be exceeding ſmooth and even; which cannot be ſo certainly done with a common pen. The uſe therefore of this part of the inſtrument is only to draw ſtrait lines; which generally ſhould be drawn very fine. The other part, which is call'd a *protracting pin*, is only a ſhort piece of fine ſteel wire, fix'd in one end of the other part of the handle: and its uſe is to ſet off angles from the protractor, as ſhall be hereafter ſhewn in deſcribing that inſtrument.

Of the parallel Ruler.

THIS inſtrument conſiſts only of two equal rulers, ſo connected to each other by moveable croſs-pieces fix'd parallel to each other, and lying aſlant, when the two rulers are cloſed, or croſſing each other with a joint in the middle, that

to whatever degree the rulers are opened, they are ſtill kept in a true parallel poſition to each other; by which means, one part being ſet true upon any line, another line may be drawn by the other part of the ruler exactly parallel to that whereon the firſt is placed; which expedient is of great uſe in delineating moſt ſorts of draughts, particularly in plans of architecture, both military and civil; and in reducing a multangular figure to a triangle, for the more accurate and ready finding the content.

Of the Protractor.

THE protractor is commonly a ſemi-circle, on whoſe chord or diameter *Fig.* 1, is mark'd its centre, and whoſe arch is divided into 180 equal parts, called degrees; being the half of 360, which every whole circle is ſuppoſed to be divided into. *(See fig.* 1. *plate I.)* But for caſes of inſtruments, it is frequently made in form of a parallelogram, upon three ſides of which the ſame diviſions are laid down from a centre, mark'd on the fourth (as in the plate fronting the title, in the figure mark'd C). Every 10 of theſe degrees are numbered, and every fifth diſtinguiſhed with a longer mark than the others, for the greater eaſe in reckoning. They are uſually numbered both ways, *viz.* from right to left, and from left to right, for the more readily laying down an angle

angle from either end of a given line. The ſide to be applied to the paper is made flat, and that whereon the degrees are mark'd is fil'd ſo ſlopeing, as to render the edges thin for the greater exactneſs in ſetting off, or meaſuring an angle; which are all the uſes of this inſtrument as a protractor, and perform'd in the following manner:

1. If it was required to lay down an angle of 60 degrees, from the point A of the line A B; lay the diameter of the protractor on the line A B, ſo that the centre of the inſtrument may fall upon the point A; then with your protracting pin make a mark exactly againſt the number 60 upon the limb of your inſtrument; ſo ſhall a line drawn through the ſaid mark to the point A, form an angle of 60 degrees. *Fig.* 2.

2. If it be required to find the content of an angle given, as in the foregoing figure the angle B A C; lay the diameter of the protractor on the line A B, ſo that the centre may fall exactly upon the point A; then ſhall the degree on the limb of the inſtrument cut by the line A C, ſhew the content of the angle as before, 60 degrees.

On the reverſe of a protractor, when made in form of a parallelogram, (*Vide* figure mark'd D in the plate fronting the title) are uſually laid down ſeveral ſcales, or lines of equal parts of different proportions, that is, of 45, 40, 35, 30, 25,

25, and 20 parts to an inch, diſtinguiſh'd by the ſaid numbers prefixed, thoſe of 20 and 40 being commonly diagonally divided; likewiſe lines of chords of different radius's; and if the diagonal ſcales be laid down within the vacant ſpace on the face of the protractor, (as in fig. C.) there may be room on the reverſe (as in fig. D.) for all the lines uſually placed on the inſtrument, called the *plain ſcale*, as well as the before-mentioned lines of equal parts, *&c.* In giving therefore the conſtruction and uſe of the plain ſcale, I ſhall ſufficiently deſcribe all the lines ever laid down on the reverſe of a protractor, and ſhew their ſeveral uſes and application in practice. But firſt I ſhall ſhew the uſe of theſe ſeveral ſcales or lines of equal parts, both as they are ſimply and diagonally divided.

Of the Uſe of Scales, or Lines of equal Parts.

1. *Simply divided (Vide* fig. D.) A line of equal parts is no more than a ſcale of meaſure in miniature, for laying down by way of plan, lengths taken by any known meaſures, as chains, yards, feet, *&c.* each part on the ſcale anſwering accordingly to one chain, one yard, or one foot, *&c.* The plan therefore will be the greater or leſs, as the ſcale uſed contains more or leſs parts in the ſpace of an inch. Note, the firſt diviſion on every ſcale is ſubdivided into 10 equal parts, which

which ſmaller diviſions are the parts to be underſtood, when we ſay it is a ſcale of 20 or 30, *&c.* If therefore theſe leſſer diviſions be taken as units, and each repreſent one league, one mile, one chain, one yard, or one foot, *&c.* the larger diviſions will conſequently be tens, tho' number'd with ſingle figures; ſo that to ſet off 36 leagues, miles, chains, yards or feet, *&c.* extend the compaſſes from 3 of the larger diviſions, to 6 reckon'd backwards upon the ſmaller, and that extent laid down on your plan ſhall accordingly repreſent 36 leagues, miles, chains, yards or feet, actually meaſured in the thing repreſented. To adapt theſe ſcales to foot meaſure, you will likewiſe find the firſt diviſion of each duodecimally divided, above the decimal diviſion, the halves and quarters of which are diſtinguiſhed by longer marks than the reſt, which are generally only dots; ſo that to lay down any number of feet and inches, as ſuppoſe 8 F. 9 I. extend the compaſſes from 8 of the larger diviſions, to 9 of the upper ſmaller diviſions; and the ſaid extent laid down on your plan, ſhall repreſent by whatever ſcale it is taken from, 8 F. 9 I. in length actually meaſured. This may ſuffice for thoſe ſcales which are only ſimply divided.

2. *Diagonally divided (Vide* fig. C.) For thoſe which are more accurately divided by diagonal lines, as one of the larger diviſions are thereby exactly divided into 100 equal parts, if the ſcale contains

contains 10 of the larger diviſions, any number under 1000 may thereby be accurately laid down.

The projection of theſe diagonal ſcales is in this manner: Firſt, draw eleven parallel lines, at equal diſtances; (*vide* fig. C.) the whole length of which being divided into a certain number of equal parts, according to the length of the ſcale, by perpendicular parallels, let the firſt diviſion be again ſubdivided into ten equal parts, both above and below; then drawing the ſeveral oblique lines from the firſt perpendicular below to the firſt ſubdiviſion above, and from the firſt ſubdiviſion below to the ſecond ſubdiviſion above, &c. the whole firſt ſpace ſhall thereby be exactly divided into 100 equal parts; for as each of the ſubdiviſions is one tenth part of the whole firſt ſpace or diviſion, ſo each parallel above it is one tenth of ſuch ſubdiviſion, and conſequently one hundredth part of the whole firſt ſpace; and if there be ten of the larger diviſions, one thouſandth part of the whole ſcale. If therefore the larger diviſions be accounted as units, the firſt ſubdiviſions will be tenth parts of an unite, and the ſecond ſubdiviſions, mark'd by the diagonals upon the parallels, hundredth parts of an unit; if the larger diviſions be reckon'd tens, the firſt ſubdiviſions will be units, and the ſecond tenth parts; and if the larger diviſions be accounted as hundreds, the firſt ſubdiviſions will be tens, and the ſecond units. The numbers therefore 576. 57, 6. 5, 76. are all

expreſſible by the ſame extent of the compaſſes; *viz.* ſetting one foot in number 5 of the larger diviſions, extend the other along the ſixth parallel, to the ſeventh diagonal; for if the 5 larger diviſions are taken for 5 hundred, 7 of the firſt ſubdiviſions will be 70, which upon the ſixth parallel, taking in 6 of the ſecond ſubdiviſions, or 6 units, makes the whole number 576. Or, if the five larger diviſions be taken for 5 tens or 50, ſeven of the firſt ſubdiviſions will be 7 units, and the 6 ſecond ſubdiviſions, included upon the ſixth parallel, will be ſix tenths of an unit. Laſtly, if the 5 larger diviſions be only eſteem'd as five units, then will the 7 firſt ſubdiviſions be ſeven tenths, and the 6 ſecond ſubdiviſions ſix hundredth parts of an unit. And this, I think, may be ſufficient to ſhew the uſe both of the ſimple and diagonal ſcales of equal parts: I now proceed to

---

The Conſtruction and Uſe of the Plain Scale.

Having deſcribed the circle ABCD, and divided it into four quadrants, by the diameters AB and CD, croſſing each other at right angles;

Fig. 3.

1. To project the line of *Tangents:* From the end C of the diameter CD, erect the perpendicular CG; then dividing the arch CB into nine equal parts, from the centre E, through the ſeveral diviſions of the arch, draw lines, till they cut

cut the perpendicular C G, which will thereby become a line of tangents.

2. For the *Semi-tangents:* Lines drawn from the point D, through the ſame diviſions upon the arch C B, will divide the radius B E, into a line of ſemi-tangents. For the ſemi-tangent of any arch is but the tangent of half ſuch arch; and by the 20th of the 3d of *Euclid*, it is prov'd, that an angle at the centre is the double of one at the circumference.

3. For the *Secants:* Since the lines drawn from the centre through the ſeveral diviſions of the quadrant C B, to form the tangents, are the ſecants of thoſe reſpective arches, transfer thoſe lengths to the line E B continued to F, and the line E F will be a line of ſecants.

4. For the *Sines:* From the ſeveral diviſions of the arch C B, let fall perpendiculars upon the radius C E; ſo ſhall the radius C E be divided into a line of ſines, which is to be numbered from E to C for the right ſines, and from C to E for the verſed ſines. Note, the verſed ſines may be continued to 180 degrees, if the ſame diviſions be transferr'd on the other ſide of the centre E.

5. For the *Chords:* The arch C B being divided into 9 equal parts, in the points 10, 20,

30, *&c.* if therefore you imagine lines drawn from C, to the ſaid ſeveral diviſions, they will be the chords of their reſpective arches. Setting therefore one foot of your compaſſes in the point C, and transferring the ſeveral lengths C 10, C 20, C 30, *&c.* to the line C B, and the line C B ſhall thereby be made a line of chords.

Note, *Theſe ſeveral lines (which in the figure are drawn but to every* 10 *degrees) might be conſtructed to every ſingle degree, if the circle were made large enough to admit of* 90 *diſtinct diviſions in the arch of its quadrant.*

6. A line of *Rhumbs* is thus conſtructed: Divide the arch D B into 8 equal parts, in the points 1, 2, 3, 4, *&c.* then ſetting one foot of the compaſſes in D, transfer the ſeveral diſtances D 1, D 2, D 3, *&c.* from the arch to the line D B, by which means you will form a line of rhumbs, each of which will anſwer to an angle of 11° 15′.

7. For the line of *Longitude:* Divide the radius E A into 60 equal parts, (becauſe 60 miles make a degree of longitude under the equator) marking every ten with their proper number; from theſe diviſions let fall perpendiculars upon the arch A D; then having drawn the line A D, with one foot of the compaſſes in A, transfer the ſeveral diſtances, where the perpendiculars cut the arch, to the line A D; which ſhall thereby be made a line of longitude.

Now,

Now, if the ſeveral lines, with their reſpective diviſions thus projected in fig. 3. be transferr'd to the ſcale mark'd D, in the plate fronting the title, where they are diſtinguiſh'd by their proper names; and thereto be added lines of equal parts, as before deſcrib'd, the inſtrument called the *Plain Scale* will thereby be form'd.

But as upon the reverſe of ſome protractors, (particularly thoſe made by Mr. *Siſſon)* beſides the ſeveral lines already explain'd, there are two other lines laid down, *viz.* the line of latitude, and the line of hours; I ſhall likewiſe ſhew the manner how they are projected.

Projection of the Lines of Latitude, and of Hours.

1. To project the line of *Latitude:* In the ſame diagram *(viz.* fig. 3.) the radius CE being already divided into a line of ſines, laying a ruler from the point B, through every of the ſaid diviſions, mark the points cut on the oppoſite arch A C, with the numbers 10, 20, 30, *&c.* Then having drawn the right line A C, with one foot of your compaſſes in A, transfer the ſeveral interſections of the arch, to the ſaid right line; which will thereby become a line of latitude, and may accordingly be laid down on your ſcale.

2. To

2. To project the *Hour-line:* Draw the tangent IK, equal and parallel to the diameter CD; and divide half the arch of each quadrant AC and AD, from the point A, into three equal parts, which will be 15 degrees each part, for the degrees of every hour from 12 to 6; each of which parts are to be again ſubdivided into halves and quarters, *&c.* Then drawing lines from the centre of the circle, through each of theſe diviſions and ſubdiviſions, till they cut the tangent line IK, the ſaid tangent line will thereby be divided into a line of hours.

3. To theſe may be ſtill added another line, applicable to the ſame uſe, *viz.* the line of *Inclination of Meridians*, which is projected in the ſame manner as the hour-line; only divided into degrees, inſtead of time, every 15 degrees being equal to an hour.

The uſes of the ſeveral lines thus laid down on the ſcale D, *from the foregoing projection, are as follow:*

1. The *Tangents*, *Semi-tangents* and *Secants* ſerve to find the centres and poles of projected circles, in the ſtereographical projection of the ſphere, *&c.*

2. The *Sines* ſerve for the orthographical projection of the ſphere, *&c.*

3. The

3. The line of *Chords* ſerves, either to ſet off an angle from a given point in any right line, or to meaſure the quantity of an angle already laid down. The firſt is done, by opening your compaſſes to the extent of 60 degrees upon the line of chords, (which is always equal to the radius of the circle of projection) and ſetting one foot in the angular point, with that extent deſcribing an arch; then taking the quantity of the angle required, between the feet of your compaſſes, from the ſame chord-line, ſet it off from the given line upon the arch deſcribed; ſo ſhall a right line drawn from the given point, through the point mark'd on the arch, form the angle required. Thus to lay down from the point A of the line AB, an angle of 40 degrees, taking the extent of 60 degrees between the feet of your compaſſes from the line of chords, ſtrike the arch CD; then ſetting off upon the ſaid arch from D to C, the extent of 40 degrees taken from the ſaid line of chords, from the point A draw the line AC, to paſs through the point C; ſo ſhall the lines AB and AC form an angle of 40 degrees. The latter is done by deſcribing, as before, an arch with the extent of 60 degrees, and then taking the extent betwixt the lines which form the angle upon the ſaid arch; that extent, meaſur'd upon the ſame line of chords, will ſhew the quantity of the angle.

Fig. 4.

4. The

4. The line of *Rhumbs* ſerves with more readineſs than the line of chords, to lay down or meaſure the angle of a ſhip's courſe in navigation. For example, ſuppoſe a ſhip's courſe being N.E.N. it is required to lay down the angle. *Fig.* 5. Draw the line A B for the meridian, then with 60 degrees of the chords deſcribe from the point A, the arch B C; and as N.N.E. is the ſecond rhumb from the north, open your compaſſes to the ſecond rhumb, and lay off the extent upon the arch B C; ſo ſhall a right line from the point A through the point C, give the angle of the courſe B A C. Or if it were required to find the quantity of the angle of a ſhip's courſe B A C; having deſcribed the arch B C, with 60 degrees of the chords, take the diſtance of the lines upon the ſaid arch between the feet of your compaſſes; which meaſur'd upon the line of rhumbs, will ſhew the quantity of the angle.

5. The line of *Longitude* being laid down on the ſcale contiguous with a line of chords of the ſame radius, numbered the contrary way, ſhews, by inſpection, how many miles there are in a degree of longitude, in each parallel of latitude, accounting the latitude upon the line of chords, and the miles of longitude upon the line of longitude. Thus in the latitude of 30 degrees, it appears, that 52 miles make a degree of longitude; in the latitude of 60 degrees, 30 miles make a degree; and

and in the latitude of 80 degrees, 10 miles make a degree, *&c.*

6. The two lines of *Latitudes* and *Hours*, are uſed conjointly, and ſerve very readily to mark the hour-lines in the conſtruction of dials, on any kind of upright plains.

As an inſtance of which, I ſhall give one example of an horizontal dial, for the latitude of *London*, *viz.* 51° 32′.

To conſtruct an horizontal Dial, by the Lines of Latitude and Hours; for the Latitude of 51° 32′.

Firſt, draw the line E W of a convenient length, for the ſix o' clock line, and at right angles thereto, the line N S for the meridian, or 12 o' clock line, of a breadth equal to the thickneſs of the ſtyle; the interſection of which lines, *viz.* the point A, will be the centre of your dial: Then taking 51° 32′ (the latitude of the place) from the line of latitude, with one foot of your compaſſes in A, ſet off that extent on both ſides, from A to E, and from A to W; then with the whole length of the line of hours between your compaſſes, ſet one foot in E, and croſs the meridian line with the other; do the ſame on the other ſide from W, and draw *Fig.* 6.

the lines NE and NW; then taking between your compaſſes from the line of hours, the diſtance from the beginning thereof to I, lay down that diſtance both ways from N to 1, and from N to 11, likewiſe from E to 5, and from W to 7; ſet off alſo the diſtance from the beginning of the line to II on the line of hours, both from N to 2 and 10, and from E to 4, and W to 8; and laſtly, lay down the diſtance from the beginning of the line of hours to III, from N to 9, and from N to 3; which ſaid diſtance will likewiſe reach from E to 3, and from W to 9. Thus having divided your trigon into its proper diſtances, lines drawn from the centre A of the dial, through theſe ſeveral diviſions, will mark the reſpective hour-points on the limb of the dial, whether its figure be ſquare or round; and for the hours before 6 in the morning, and after 6 at night, they are eaſily found, by continuing the lines of the oppoſite hours through the centre.

Note, the ſtyle, which is generally a thin plate of braſs, muſt make an angle with the plain, equal to the latitude of the place, the angular point being fix'd juſt at the centre A, and the ſtyle ſtanding upon the meridian line, at right angles with the plain of the dial.

Of the SECTOR.

THE *Sector* is a mathematical inſtrument, taking its name from a geometrical figure, which *Euclid* thus defines: A ſector is a part of a circle, bounded by two radii or ſemidiameters, and part of the circumference, *viz.* the included arch. As an inſtrument, it conſiſts of two equal legs, moveable about a joint, like the common carpenters rule; which being each of the length of ſix inches, (tho' they may be made of any other determinate length, as in the figures mark'd A and B in the plate fronting the title, they are of 4 inches and a half) when quite open, they form an exact foot rule; and may be uſed as ſuch in taking dimenſions, being, like other common rules, divided into inches and parts.

The lines commonly laid down on the faces of this inſtrument to be us'd ſector-wiſe, are as follow: *viz.* Upon one face, (that mark'd A in the print) 1. The lines of *Lines*, or of equal parts. 2. The lines of *Chords*. 3. The lines of *Secants*. 4. The lines of *Polygons*. On the other face, (mark'd B in the print) 1. The lines of *Sines*. 2. The lines of *Tangents* to 45 degrees. 3. Other lines of *Tangents* to a leſſer radius, to ſupply the defect of the former, from 45 degrees to about 75 degrees.

Note, If the lines of leſſer tangents, and the lines of ſecants, be projected from a radius $\frac{1}{4}$ of the larger lines, and laid down upon the inſtrument to the ſame angle, (as is the practice of Mr. *Siſſon*) then, without any alteration in the opening of the legs, any extent taken on the lines of leſſer tangents or ſecants, 4 times repeated, will give the proper tangent or ſecant to the radius of the larger lines.

Theſe ſeveral lines are projected and divided as the ſame lines upon the plain ſcale, but laid down upon the ſector, (all except the lines of polygons) ſo as that they may all make one certain angle; that is, to whatever degree the ſector is opened, the diſtance will be the ſame betwixt 100 and 100 on the lines of lines, 90 and 90 on the lines of ſines, 60 and 60 on the lines of chords, and 45 and 45 on the lines of tangents. The lines of lines are each divided into 100 equal parts, each of which are again ſubdivided into halves and quarters, if the legs are of ſufficient length; and with the lines of ſines, chords and tangents, are each extended to the length of the radius of the circle from which they are projected; that is, the lines of ſines to 90 degrees, the lines of chords to 60 degrees, and the lines of tangents to 45 degrees; each being numbered at every 10 degrees from the centre to their ſeveral ends, where they are mark'd with the initial letters of their reſpective names.

Note,

Note, The correſpondent parallels of the ſeveral lines are intended for the better diſtinguiſhing the ſeveral diviſions upon each.

The lines of ſecants, and of leſſer tangents, are each projected from a circle, whoſe radius is $\frac{1}{4}$ of that from which the other lines are projected; and beginning at the length of that radius from the centre of the inſtrument, run to about 75 degrees. The tangents beginning at 45, where the larger lines of tangents end, have their degrees diſtinguiſhed by the numbers 45, 50, 60, 70, 75, and the ſecants with the numbers 10, 20, 30, *&c.* to 75; and both are mark'd, for diſtinction's ſake, with the ſmall initial letters of their names.

The lines of polygons are laid down from the centre of the joint, very near the inward edges of the inſtrument, and are numbered backwards, from the ends towards the centre, with the figures 4, 5, 6, *&c.* to 12, which comes within about three inches of the centre.

Theſe are all the lines, which are uſually laid down on this inſtrument to be uſed ſector-wiſe.

The other lines, which are placed upon, and parallel to the outward edges on both faces, and uſed as on common ſcales, the ſector being quite opened, are, on the edge itſelf, a line of *Inches*, with each inch ſubdivided into 10 equal parts; and

and on the faces, the line of *Numbers*, commonly called *Gunter's-line*, with the lines of *Artificial Sines* and *Tangents*; alſo ſometimes a line of *Hours*, with a line of *Chords*, and a line of *Latitudes*, with a line of *Inclination of Meridians*, each being diſtinguiſhed with its proper letter.

Of the Foundation and general Uſe of the Sector.

The foundation and general uſe of the ſector depends upon the 4th propoſition of the 6th book of *Euclid*; where it is prov'd, that the homologous ſides of ſimilar and equiangular triangles, are proportional to each other. Sup-
Fig. 7. poſe therefore the lines A B, A C, to repreſent any pair of lines upon the ſector, particularly the lines of lines, making an angle B A C with each other. If then the line B C be drawn, and A a, A b taken equal, and the line a b alſo drawn; as A a, or A b is to A B or A C, ſo will a b be to B C. Whence, if the lines A a, A b, be the half, the third, the fourth, *&c.* of the lines A B, A C; the line a b will accordingly be the half, the third, the fourth, *&c.* of the line B C. As ſuppoſe A B or A C be 100, and A a or A b 50; then if B C be 60, a b ſhall be 30. Hence it follows, that if the lines A B, A C, repreſent the lines of chords, ſines or tangents, that is, if the line A B or A C be the radius, and the line

line A a or A b, the chord, ſine or tangent, of ſome propoſed number of degrees to the ſaid radius A B; then the line a b will be the chord, ſine or tangent of the ſame number of degrees to the radius B C.

And here note, that lines taken upon the ſector are diſtinguiſhed by the terms *lateral* and *parallel*; thoſe being called lateral, which are found upon the ſides of the inſtrument, as A B, A C; and parallel are ſuch extents as are taken from one leg to the other, at equal diſtances from the centre of the joint, as B C, a b.

If therefore it be required to find the chord, ſine or tangent of 20 degrees, to a radius of 5 inches; open the ſector ſo that the diſtance from 60 to 60 on the line of chords may be equal to 5 inches; then will the parallel diſtance between 20 and 20, on the line of chords, be the chord of 20 degrees, to a radius of 5 inches; ſo likewiſe, the diſtance between 20 and 20 on the lines of ſines, and between 20 and 20 on the lines of tangents, will be the reſpective ſine or tangent of 20 degrees, to the ſaid radius of 5 inches.

If a chord of more than 60 degrees be required to any aſſign'd radius, as ſuppoſe the chord of 80 degrees; open the ſector, as before directed, to the radius given, and with the ſaid radius deſcribe

an

an arch ſufficiently large, as A D; then
Fig. 8. taking the chord of half the number of degrees, *viz.* 40. lay it off twice upon the ſaid arch, *viz.* from A to B, and from B to C; ſo ſhall a line drawn from A to C be the required chord of 80 degrees.

If a tangent of more than 45 degrees be required, as ſuppoſe the tangent of 70 degrees, it muſt be taken from the lines of leſſer tangents; which, if not laid down to the ſame angle as the larger lines, as in moſt ſectors they are not, then muſt the ſector be ſo opened, that the diſtance between 45 and 45, on the ſaid leſſer tangents, may be equal to the given radius; ſo ſhall the diſtance between 70 and 70 upon the ſaid lines of leſſer tangents, be the tangent of 70 degrees, to the radius given. But if the lines of leſſer tangents are made (as they ſhould be) to $\frac{1}{4}$ of the radius of the larger, and laid down to the ſame angle; then the tangent of any required number of degrees, either more or leſs than 45, may be taken off, without any alteration in the opening of the ſector; for in the inſtance above of 70 degrees, the diſtance between 70 and 70 on the line of leſſer tangents, 4 times repeated, will be the tangent of 70 degrees, to the radius ſo ſet off between 45 and 45 on the line of larger tangents.

To find the ſecant of any propos'd number of degrees to a given radius, as ſuppoſe the ſecant of

of 60 degrees, to a radius of two inches; open the ſector to the diſtance of 2 inches between 0 and 0, on the lines of ſecants; ſo ſhall the diſtance between 60 and 60, upon the ſaid lines, be the ſecant of 60 degrees, to the radius of 2 inches: Or if, according to the above remark on the leſſer tangents, the lines of ſecants are projected to $\frac{1}{4}$ of the larger radius, and form the common angle; the diſtance between any propoſed point, 4 times repeated, will give the proper ſecant to the radius the larger lines are open'd to.

If the contrary of any of theſe operations be required, that is, if a given right line be the chord, ſine, tangent or ſecant of any certain number of degrees, as ſuppoſe 20, and the radius be ſought; open the ſector to the length of the given line, in the points 20 and 20 of the lines of chords, ſines, tangents or ſecants, according as the ſaid line is either chord, ſine, tangent or ſecant; and the diſtance between 60 and 60 on the chords, between 90 and 90 on the ſines, between 45 and 45 on the tangents, and between 0 and 0 on the ſecants, ſhall be the radius to the given line, whether it be chord, ſine, tangent or ſecant.

This may ſuffice to ſhew the nature, general uſe, and excellence of this inſtrument; it evidently appearing, from what has been ſaid, that the *Sector* is, as it were, an univerſal *Plain Scale*, to any radius not greater than the extent of the inſtru-

ment itſelf, when quite open, or leſs than the diſtance between the numbers at the ends of the reſpective lines, when quite ſhut.

And as the ſeveral lines make equal angles with each other reſpectively, they are thereby adapted to the working of proportions in equal parts and ſines, equal parts and tangents, *&c.* ſo that among other things, the ſeveral caſes of Trigonometry may very readily be reſolved by the ſector. Some inſtances of which ſhall be hereafter given; but firſt I ſhall ſhew ſome particular uſes of the lines of lines, and of the lines of polygons.

Of the particular Uſe of the Lines of Lines.

As lines of equal parts, their uſe is the ſame with ſuch lines on common ſcales, ſerving to lay down any given length; but as they are laid down ſector-wiſe, they have other various uſes, ſome of the principal of which are ſhewn in the following problems.

PROBLEM I.

To divide a given Line into any Number of equal Parts.

Take the extent of the given line between the feet of your compaſſes, and ſet off that extent as a parallel between the legs of your ſector, in the points expreſſing the number of parts into which the

the line is to be divided; ſo ſhall the parallel diſtance between 1 and 1 divide the given line into the parts required. For example, ſuppoſe the line A B were given to be divided into 6 equal parts; ſet off the extent of the line A B, betwixt the legs of the ſector in the points 6 and 6, and the parallel diſtance betwixt 1 and 1, *viz.* A C, ſhall be the $\frac{1}{6}$ part of the line A B. *Fig.* 9.

If the given line be of too great extent to be applied to the legs of the ſector, take one half, or one fourth of it; which being divided, as above directed, into the parts required, the double, or quadruple of one of thoſe parts, will accordingly divide the whole line into the number of parts propoſed.

PROBLEM II.

To divide a Line in the ſame manner as another is divided.

Lay down the divided line laterally on both ſides of the ſector, from the centre, and mark the point of its extenſion; then opening the ſector to the extent of the ſecond line, in the terms of the firſt; apply likewiſe the ſeveral parts of the firſt line laterally on the legs of the ſector; ſo ſhall the ſeveral parallels, in the terms of thoſe parts, be the correſpondent parts in the line to be divided. Thus, if the line C D were to be divided in the manner as the line A B; *Fig.* 10.

placing AB on the lines of lines, in AB and AC, open the ſector to the extent of CD, in the terms BC; the ſector remaining in this poſition, ſet off the parts AE and AF, of the line AB, on both legs of the ſector, in AE and AF, ſo ſhall the parallel EE give the diviſion CG, and the parallel FF, the diviſion GH, on the line CD to be divided.

PROBLEM III.

To find the Proportion between two, or more given Lines.

The proportion between any given lines may be meaſured upon either of the lines of lines, as on other ſcales of equal parts, without opening the inſtrument. But to perform the operation ſectorwiſe, open the ſector, ſo that the extent between 100 and 100, may be equal to the greater of the given lines; then taking the leſſer lines ſeverally between your compaſſes, carry them along the legs of the ſector, till both points reſt exactly on the ſame number upon the lines of lines; which numbers will accordingly give their proportion to 100. Thus if it were required *Fig.* 11. to find the proportion between the lines AB and CD; having ſet off the extent of the longer line AB, betwixt the points of 100 and 100, apply the ſhorter line CD parallel to the former, and you will find it cut the lines of lines, in the points 80 and 80. The proportion therefore

therefore of C D to A B is as 80 to 100; or in ſmaller numbers, as 4 to 5.

If the greater line A B be too long to be applied in the points 100 and 100, then ſuppoſing the leſſer line C D 100, cut off A E upon the greater line, equal to C D, and the part A E being ſet off on the ſector, as before directed, in the points 100 and 100, the part E B will be found to cut the lines of lines in the numbers 24 and 24, ſo that the proportion of the part E B, to the part A E, will be found to be as 24 to 100; therefore the proportion of the line C D, to the line A B, will this way be found to be as 100 to 124.

PROBLEM IV.

To increaſe or diminiſh a Line in any given Proportion.

Set the extent of the given line betwixt the legs of the ſector, in the points of the number given, on each of the lines of lines; and the parallel diſtance, betwixt the points of the number required, will give the line ſought. Thus, if the line A is to be increaſed in the proportion of 3 to 7; ſet off the length of the line A, betwixt 3 and 3, on the lines of lines; ſo ſhall the parallel diſtance betwixt 7 and 7, be the increaſed line B ſought. On the contrary, if the line B was to be diminiſhed in the

Fig. 12.

the proportion of 7 to 3, ſet off the line B betwixt 7 and 7, and the parallel diſtance betwixt 3 and 3 ſhall be the diminiſhed line A ſought. Note, it may be ſometimes more convenient to work with the equimultiples of the numbers given, which will produce the ſame effect; thus, for the proportion of 3 to 7, you may take the numbers 6 to 14, 9 to 27, 12 to 28, or 30 to 70, *&c.*

PROBLEM V.

To find a third proportional to two given Lines.

Lay down both the given lines laterally on the legs of the ſector, obſerving the points of their extenſion; then taking the ſecond line between your compaſſes, open the ſector to its extent in the terms of the firſt line; ſo ſhall the parallel diſtance, between the terms of the ſecond line, be the third proportional ſought. For example, let the two given lines be A and B, *Fig.* 13. which being laid down on the ſides of the ſector from the centre A, ſuppoſe the terms of the firſt line to be B B, and the terms of the ſecond C C; then opening the ſector in the terms B B, to the extent of the ſecond line B, the parallel diſtance between C C ſhall be the third proportional ſought. For as A is to B, ſo is B B, equal to the line B, to C C.

PRO-

PROBLEM VI.

To find a fourth Proportional to three Lines given.

Let the firſt and third lines be both laid down laterally on the legs of the ſector, from the centre; then opening the ſector in the terms of the firſt line, to the extent of the ſecond line; the parallel diſtance, between the terms of the third line ſhall be the fourth proportional. For example, let A, B and C, be the three lines given; ſet off A and C on the ſides of the ſector, from the centre A, marking the terms of their extenſion B B and C C; then taking the ſecond line B, open the ſector to its extent, in the terms of the firſt line A, *viz.* B B; and the parallel diſtance betwixt C C, the terms of the third line C, ſhall be the fourth proportional ſought. *Fig.* 14.

Note, in Geometry, as well as in Arithmetick, it is not neceſſary that all the proportionals be of one denomination, but only that the fourth found correſpond with the ſecond, as the third with the firſt; therefore the firſt and third proportionals may be meaſured by one ſcale, and the ſecond and fourth by another: Or their reſpective proportions to each other may be found, as directed in *Prob.* III.

PRO-

PROBLEM VII.

To find a Right Line nearly equal to the circumference of a given Circle.

Since the proportion of the diameter of a circle to its circumference is nearly as 3. 18 to 10; therefore opening the ſector to the length of the diameter of the circle propoſed, in the points on the lines of lines, anſweringto the number 3. 18, the parallel diſtance between 10 and 10 will be the length of a line nearly equal to the circumference of the given circle.

PROBLEM VIII.

To open the Sector ſo that the two Lines of Lines (and conſequently the others reſpectively, if they are laid down as they ought, at equal angles) may ſtand at right angles with each other.

Since by the 47th propoſition of the 1ſt book of *Euclid* it is demonſtrated, that in a right-angled triangle, the ſquare of the hypotheneuſe is equal to the ſum of the ſquares of both the legs; therefore, if the whole lateral length of one of the lines of lines, taken as 10 equal parts, be ſet over from 8 on one leg to 6 on the other, the two lines of lines (and conſequently, the reſt reſpectively) ſhall ſtand at right angles with each other. For 64, the ſquare of 8, added to 36, the ſquare of 6, makes 100, equal to the ſquare of 10.

To

To theſe few problems, peculiar to the lines of lines, I ſhall add one or two of a more general nature.

PROBLEM IX.

To open the Lines upon the Sector, or the Edges of the inſtrument itſelf, to any propoſed angle.

Take the quantity of the angle propoſed, laterally from the centre, on one of the lines of chords, and ſet it off as a parallel betwixt 60 and 60 on the ſaid lines; ſo ſhall the two lines of chords, and every other pair of lines, ſtand reſpectively with each other at the determined angle. Thus, to open the lines to an angle of 20 degrees, ſet off the lateral extent of 20 degrees taken from the centre, upon either of the lines of chords, as a parallel betwixt 60 and 60 upon the ſaid lines; and the two lines of chords, and conſequently all the reſt, each being laid down to the ſame angle, ſhall accordingly form an angle of 20 degrees, each with the other reſpectively. And if (as in the print prefix'd to this work) every pair of lines form with each other an angle of 6 degrees, when the ſector is quite ſhut, it is but adding 6 degrees to the quantity of the angle propoſed, in taking the lateral extent, and the parallel ſo ſet off ſhall ſet the edges of the inſtrument itſelf to the angle required.

PROBLEM X.

The Sector being opened, to find the Quantity of the Angle, which either the ſeveral Lines, or the Edges of the Inſtrument, make with each other.

This problem is but the reverſe of the former: For if the parallel diſtance betwixt 60 and 60 on the line of chords, be applied laterally from the centre, on either of the ſaid lines, the degrees of its extenſion are the meaſure of the angle the ſeveral lines reſpectively make with each other; deducting therefore 6 degrees from the quantity ſo found, for the angle the ſeveral lines make with each other, when the inſtrument is quite ſhut; and the remainder will be the quantity of the angle formed by the edges of the inſtrument.

Of the Uſe of the Lines of Polygons.

The lines of polygons are chiefly contrived for the ready diviſion of the circumference of a circle into any number of equal parts from 4 to 12, that is, as a ready means to inſcribe regular polygons of any given number of ſides, from 4 to 12, within a given circle: To do which, ſet off the radius of the given circle, (which is always the ſide of the inſcribed hexagon) as a parallel betwixt 6 and 6, upon the ſaid lines; ſo ſhall the parallel diſtance betwixt 5 and 5, be the ſide of a pentagon; between 7 and 7, the ſide of a heptagon;

tagon; between 8 and 8, the ſide of an octagon, *&c.* All which is too plain, even to need an example.

N. B. All ſuch regular polygons, whoſe number of ſides will exactly divide 360, (the number of degrees into which all circles are ſuppoſed to be divided) without a remainder, may likewiſe be very readily ſet off upon the circumference of a circle, from the lines of chords; for laying down the radius of the circle, as a parallel betwixt 60 and 60, upon the lines of chords; the ſector remaining ſo opened, having divided 360 by the number of ſides, the parallel diſtance betwixt the numbers of the quotient ſhall be the ſide of the polygon required; thus, for an octagon, take the extent betwixt 45 and 45; and for a pentedecagon, the extent betwixt 24 and 24, *&c.*

If it be required to form a polygon, upon a given right line; ſet off the extent of the given line, as a parallel betwixt the points, upon the lines of polygons, anſwering to the number of ſides, of which the polygon is to conſiſt; as for a pentagon, betwixt 5 and 5; or for an octagon, betwixt 8 and 8; ſo ſhall the parallel diſtance betwixt 6 and 6 be the radius of a circle, whoſe circumference ſhall be divided, by the given line, into the number of ſides required.

The lines of polygons are likewiſe uſeful in deſcribing, upon any given line, an iſoſceles triangle, whoſe baſe angles ſhall each be double that at the vertex. For, taking the given line betwixt your compaſſes, open the ſector, till that extent reaches from 10 on one leg to 10 on the other; then ſhall the parallel diſtance betwixt 6 and 6 be the length of the two equal ſides of the triangle ſought.

Before we proceed to the manner of working proportions upon the ſector, it will be neceſſary to conſider the nature of the lines of artificial numbers, ſines and tangents; becauſe as the ſame proportions may likewiſe be work'd upon theſe artificial lines, ſo one method of working will ſerve as a proof of the other.

Of the Lines of Artificial Numbers, Sines and Tangents.

Theſe ſeveral lines, which are uſually laid down upon ſectors parallel to the outward edges, in the ſame manner as upon other ſcales, are only the logarithms of the natural numbers, ſines, and tangents, thus transferred to a ſcale.

1. The line of numbers, or *Gunter*'s line, as it is commonly called, is a line of geometrical proportion, divided into 9 unequal parts, beginning

ning at 1 towards the left hand, and numbered on with 2, 3, 4, 5, *&c.* to 10, about the middle of the line; where another radius begins, and the ſame diviſions are repeated, numbered as before to 10, at the end of the line on the right hand. Each of theſe primes, or firſt grand diviſions, are ſubdivided, according to the ſame ratio, into 10 other parts, and each of theſe ſubdiviſions (if the line be of ſufficient length) ſhould again be ſubdivided into 10 other leſſer parts. But upon pocket-ſectors, which, when opened, are but 12 inches in length, only the part from 1 in the middle, to 2 towards the right hand, is a ſecond time divided, and that but into 5 parts inſtead of 10, every one of which muſt therefore be accounted as 2 centeſms. In numbering therefore upon the line, (wherein conſiſts the greateſt difficulty) the figures 1, 2, 3, *&c.* which denote the primes, may be taken arbitrarily, either as units, tens, hundreds, or thouſands; or they may repreſent tenth, hundredth, or thouſandth parts of an unit.

If 1, at the beginning of the line, be taken for unity, then 1 in the middle will be 10, and 10 at the end 100; but if the firſt 1 be accounted 10, then 1 in the middle will ſtand for 100, and 10 at the end for 1000; again, if the firſt 1 be reckon'd 100, then 1 in the middle will be 1000, and 10 at the end 10000.

When

When therefore the firſt 1, or prime, repreſents 10 units, the figures 2, 3, 4, *&c.* to 1 in the middle, will ſtand for 20, 30, 40, *&c.* and each tenth, or ſubdiviſion in the firſt radius of the line, will ſignify 1 unit, and each centeſm in thoſe tenths (if there be any) will be $\frac{1}{10}$ part of an unit; 1 in the middle will be (as before obſerved) 100, and the figures 2, 3, 4, *&c.* following 200, 300, 400, *&c.*; each tenth, or ſubdiviſion in the ſecond radius, will denote 10 units, and each centeſm 1 unit. Again, let the firſt 1 repreſent 100, then the figures 2, 3, 4, *&c.* will ſignify 200, 300, 400, *&c.* 1 in the middle 1000, and 10 at the end 10000; according to this ſuppoſition, in the firſt radius, each tenth of a prime will be 10 units, and each centeſm 1 unit; and in the ſecond radius, each tenth of a prime 100, and each centeſm 10.

In accounting decimal fractions upon the line; if 1 in the middle of the line be accounted as unity, then will each prime in the firſt radius denote 1, each tenth of a prime ,01, and each centeſm ,001. If 10 at the end of the line to the right hand be accounted as unity, the whole firſt radius will repreſent 1, and the numbers 2, 3, 4, *&c.* in the ſecond radius 2, 3, 4, *&c.* every prime in the firſt radius, and every tenth of a prime in the ſecond radius, will ſignify ,01, or one hundredth part of unity; and every tenth of a prime in the firſt radius, or centeſm in the ſecond, will denote ,001, or one thouſandth part of unity.

The

The numeration of the line thus explain'd, let it now be propoſed to find the point thereon, anſwering to the number 436. For the 4 hundred, take the 4 firſt primes next the left hand; for the ſecond figure 3, take 3 tenths of the grand diviſion betwixt 4 and 5, and for the 6 units, reckon 6 centeſms, or 6 parts of the next tenth; ſo that the extent from 1 at the beginning of the line, to that point, will expreſs the number 436. The ſame point will likewiſe repreſent the numbers 43, 6. 4, 36. or ,436; if the firſt 1 be accordingly accounted 10, 1, or $\frac{1}{10}$ of unity.

To multiply upon the line, extend your compaſſes from 1 at the beginning, to the point repreſenting the number of your multiplier; the ſame extent will reach from the number of your multiplicand, to the product; thus, if 125 were given to be multiplied by 42, extend the compaſſes from 1 to 42, and the ſame extent will reach from 125 to 5250.

To divide upon the line, extend the compaſſes backwards from the number of the diviſor, to unity; the ſame extent, laid the ſame way, will reach from the number of the dividend to the quotient: Thus, if 5250 were given to be divided by 125, extend the compaſſes backwards from 125 to unity, the ſame extent will reach the ſame way, from 5250 to 42.

2. The

2. The line of artificial ſines conſiſts only of the logarithms of the natural ſines, transferr'd from a table of logarithms to the ſcale; they are number'd from the left to the right, with the figures 1, 2, 3, *&c.* to 10, which ſtands about the middle of the line; and ſo forward with 20, 30, 40, *&c.* to 90, at the end on the right. In the firſt part of the line, the grand diviſions each repreſent one degree; ſo that if each prime be ſubdivided into 12 parts, (as they commonly are upon ſectors) each ſubdiviſion will ſignify 5 minutes. In the latter part of the line, the grand diviſions, which are each 10 degrees, being ſubdivided into 10 parts, each ſubdiviſion will repreſent 1 degree; and according as they are again ſubdivided into 4, 3 or 2 parts, ſuch ſecond ſubdiviſions contain 15, 20, or 30 minutes each.

3. What has been ſaid of the line of ſines is likewiſe to be underſtood of the line of artificial tangents, whoſe diviſions begin alſo at 1, and run on to 10 in the middle of the line, ſignifying ſingle degrees; in the ſecond part it runs on with 20, 30, *&c.* to 45, which ſtands at the end of the line; then returns back again to 90, where you begun, as is evident from the inſpection of the lines themſelves.

The uſe of theſe lines is in working proportions, whether arithmetical or geometrical; particularly they are of very ready ſervice in trigonometrical ſolutions.

The

The method of working with them is thus: In all proportions you have three terms given, to find a fourth. Seek out therefore the firſt term, whether number, ſine, or tangent, on its proper line; and in that point ſet one foot of your compaſſes, extending the other to the ſecond or third term, which-ever of them is of the ſame name with the firſt; the ſame extent laid from the other term, the ſame way, will reach to the fourth term required.

Thus, to work the following proportion; as the ſine of 52° 30′ to the number 85; ſo is radius, or the ſine of 90°, to the fourth number required. Set one foot of your compaſſes in the line of artificial ſines on 52° 30′, and extend the other foot to 90° on that line, the ſame extent will reach from 85 on the line of numbers to 107, the fourth number required. And thus are all queſtions in proportion work'd by the artificial lines of numbers, ſines and tangents; as will more fully be ſeen in the following ſection.

Of the manner of working Proportions on the Sector, both by the conjoint Uſe of the Lines of Lines, with the Lines of natural Sines, Tangents, &c. *as alſo by the artificial Lines of Numbers, Sines and Tangents.*

Having already, in treating of the reaſon and general uſe of this inſtrument, ſhewn the particular uſe of the ſeveral lines of chords, ſines, tangents, and ſecants laid down thereon, and how univerſal their application is thereby made, above what it is upon the plain ſcale; I now proceed to ſhew the conjoint uſe of the lines of lines, with the lines of natural ſines and tangents, as they are laid down ſectorwiſe; and alſo, the uſe of the artificial lines of numbers, ſines, and tangents, in working proportions; which I ſhall exemplify in the reſolution of the ſeveral caſes of plain Trigonometry, both right-angled, and oblique-angled.

The Seven Caſes of Right-angled Plain Triangles.

CASE I.

The angles, and one of the legs being given, to find the other leg.

As, ſuppoſe in the triangle A B C, *Fig.* 15. the angle A is 36 degrees, and the baſe A B

A B 75 feet, it were required to find the height of the perpendicular B C.

The trigonometrical proportion for working this caſe is, as radius to the tangent of the angle A, ſo is the leg A B to the leg B C.

To work which upon the ſectoral lines,

Take with your compaſſes, on either of the lines of tangents, the tangent of 36 degrees laterally from the centre, and ſet off that extent parallel-wiſe from 45 to 45, on the lines of tangents; with this opening of the ſector, take between the feet of your compaſſes the parallel extent betwixt 75 and 75, the length of the given leg, on the lines of lines; which extent, applied laterally on either of the lines of lines, will reach to 54, for the length of the other leg; ſo that the perpendicular B C is thereby found to be 54 feet.

Upon the artificial lines,

Set one foot of your compaſſes in 45, (the radius) upon the line of tangents, and extend the other backwards to 36; the ſame extent will reach upon the line of numbers, from 75, the length of the given leg A B, to 54, the length of the required leg B C.

CASE II.

The angles, and one of the legs being given, to find the Hypothenuſe.

As, ſuppoſe in the former triangle, the baſe A B, as before, 75 feet, the angle A 36 degrees, and conſequently the angle C 54 degrees; and it were required to find the length of the hypothenuſe A C.

Proportion. As the Sine of the angle C, to the radius, ſo is the baſe to the hypothenuſe.

To work which upon the ſectoral lines,

Take, with your compaſſes on either of the lines of ſines, the ſine of 54 degrees (the quantity of the angle C) laterally from the centre, and ſet off that extent, as a parallel betwixt 90 and 90, on the lines of ſines; the ſector remaining in that poſition, take between the feet of your compaſſes the lateral diſtance from the centre to 75, (the length of the baſe) on either of the lines of lines; and that extent applied parallel-wiſe, will reach from 93 to 93 upon the lines of lines, the length of the hypothenuſe ſought.

Upon the artificial lines,

Set one foot of your compaſſes in 54, (the ſine of the angle C) upon the line of ſines, and extend the

the other to 90 (the radius); the ſame extent will reach upon the line of numbers, from 75, the length of the baſe, to 93, the length of the hypothenuſe required.

CASE III.

The Hypothenuſe and angles being given, to find either of the legs.

As, ſuppoſe in the foregoing triangle, the hypothenuſe A C 93, the angle A 36 degrees, and conſequently the angle C 54 degrees; and it were required to find the length of the baſe A B.

Proportion. As radius to the ſine of the angle C, ſo is the hypothenuſe to the baſe.

To work which upon the ſectoral lines,

Setting one foot of your compaſſes on the centre of one of the lines of ſines, extend the other laterally to 54 degrees, and ſet off that extent as a parallel betwixt 90 and 90 on the ſaid lines of ſines; the ſector continuing ſo opened, take the parallel diſtance between 93 and 93, the length of the hypothenuſe, on the line of lines; and applying it laterally from the centre, upon one of the ſaid lines, the extent will be found 75, for the length of the baſe required.

Upon

Upon the artificial lines,

Set one foot of your compaſſes in 90, on the line of ſines, and extend the other backwards to 54, the ſine of the angle C; the ſame extent will reach, upon the line of numbers, from 93, the length of the hypothenuſe, backwards to 75, the length of the baſe required.

CASE IV.

The legs being given, to find the angles.

As, ſuppoſe in the foregoing triangle, the baſe AB, as before, 75 feet, and the perpendicular BC 54 feet, and it were required to find the quantities of the angles A and C.

Proportion. As the leg AB to the leg BC, ſo is radius to the tangent of the angle at A; whoſe complement to a quadrant will be the angle at C.

To work which upon the ſectoral lines,

Setting one foot of your compaſſes on the centre, extend the other laterally on one of the lines of lines to 54, the length of the perpendicular BC, and ſet off that extent as a parallel between 75 and 75, the length of the baſe, upon the ſaid lines of lines; the ſector continuing thus opened, take

take the parallel radius, or extent between 45 and 45 on the lines of the tangents, between your compaſſes, which laid down laterally from the centre, on either of the lines of tangents, will give 36° for the quantity of the angle A; and that, ſubtracted from 90, will leave 54°, for the quantity of the angle C.

Upon the artificial lines,

Set one foot of your compaſſes upon the line of numbers, in 75, the length of the baſe; and extend the other backwards to 54, the length of the perpendicular; the ſame extent will reach from 45 (radius) on the tangents, to 36 the tangent of the angle A.

CASE V.

The legs given, to find the hypothenuſe.

As, ſuppoſe in the foregoing triangle, the baſe A B is 75, and the perpendicular B C 54; it were required to find the length of the hypothenuſe A C.

To work this Caſe upon the ſectoral lines,

Open the inſtrument to a right angle (by *Prob.* the laſt, of the uſes of the lines of lines); then taking between your compaſſes the ſlant extent from 75, on one of the ſaid lines of lines,

to

to 54 on the other, apply the ſaid extent laterally from the centre, on either of the ſaid lines, and you will find 93 for the length of the hypothenuſe required.

Upon the artificial lines,

Firſt find the angles, by *Caſe* the 4th; then the hypothenuſe, by *Caſe* the 2d.

CASE VI.

The hypothenuſe and one of the legs given, to find the angles.

As, ſuppoſe in the foregoing triangle, the hypothenuſe A C 93, and the baſe A B 75; and it were required to find the angles A and C.

Proportion. As the hypothenuſe to the baſe, ſo is radius to the ſine of the angle at C.

To work which upon the ſectoral lines,

Setting one foot of your compaſſes in the centre, extend the other laterally on one of the lines of lines to 93, the length of the hypothenuſe AC; this extent ſet off parallel-wiſe, as a radius betwixt 10 and 10, on the ſaid lines of lines; then from the centre laterally on one of the lines of lines, taking the extent of the baſe A B 75 between your compaſſes, run that diſtance parallel-

wiſe

wiſe along the lines of ſines, till the feet reſt in like numbers, which will in this example be at 54 degrees, the quantity of the angle C, oppoſite to the baſe; which being ſubtracted from 90, there will remain 36 degrees, the quantity of the angle A.

Upon the artificial lines,

Set one foot of your compaſſes upon the line of numbers, in 93, the length of the hypothenuſe, and extend the other backwards to 75, the length of the baſe; the ſame extent will reach upon the line of ſines, from 90 (radius) backwards to 54, the ſine of the angle C; which, ſubtracted from 90, leaves 36 for the angle A.

CASE VII.

The hypothenuſe, and one of the legs, being given, to find the other leg.

As, ſuppoſe (as before) in the foregoing triangle, the hypothenuſe A C 93, and the baſe A B 75, and it were required to find the perpendicular B C.

To work this Caſe upon the ſectoral lines,

Open the ſector to a right angle (by *Prob.* the laſt, of the uſes of the lines of lines); then taking between your compaſſes the length of the hypothenuſe A C 93, from the centre, upon either of

the lines of lines, ſet one foot in 75, the length of the baſe A B upon one line; and the other foot, being turned towards the centre, will reſt upon the other line in the point 54, the length of the perpendicular B C required.

Upon the artificial lines,

Firſt find the angles, (by *Caſe* the ſixth) then to find the length of the perpendicular, ſet one foot of your compaſſes on the line of ſines in 90, (radius) and extend the other backwards to 36, the ſine of the angle A; the ſame extent will reach, on the line of numbers, from 93, the length of the hypothenuſe, backwards to 54, the length of the perpendicular required.

The Six Caſes of oblique-angled plain Triangles.

CASE I.

Two ſides, and an angle oppoſite to one of them, being given, to find the other oppoſite angle.

Fig. 16. As, ſuppoſe in the triangle A B C, the ſide A C being 65 leagues, and the ſide B C 54 leagues, and the angle A oppoſite to the ſide B C 35° 30′, it were required to find the quantity of the angle B.

Propor-

Proportion. As the ſide oppoſite to the given angle, to the ſine of the given angle; ſo is the ſide oppoſite to the angle ſought, to the ſine of the angle required.

To work which upon the ſectoral lines,

Setting one foot of your compaſſes on the centre, extend the other laterally on the lines of lines to 54, the length of the ſide B C; which extent ſet off as a parallel betwixt 35° 30′, and 35° 30′ on the lines of ſines, the quantity of the given angle A; then from the centre of the lines of lines, take the length of the ſide A C 65 between your compaſſes, and run that diſtance parallel-wiſe along the lines of ſines, till the feet reſt in like numbers, which in this example will be at 44° 15′ nearly; and that ſhall be the quantity of the angle B, oppoſite to the ſide A C.

If you would know the quantity of the remaining angle C, ſubtract the ſum of the angles A and B from 180 degrees (the ſum of the three angles of every triangle); the remainder 100° 15′, ſhall be the quantity of the angle C.

Upon the artificial lines,

Set one foot of your compaſſes on the line of numbers in 54, the length of the ſide B C, oppoſite to the given angle A, and extend the other to 65, the length of the ſide A C; the ſame ex-

tent will reach upon the line of ſines, from 35° 30′, the given angle A, to 44° 15′, the quantity of the required angle B.

CASE II.

The angles, and one ſide being given, to find either of the other ſides.

As, ſuppoſe in the foregoing triangle, the ſide BC, as before, being 54 leagues, the angle A 35° 30′, the angle B 44° 15′, and the angle C 100° 15′, the ſides AB and AC were required.

Proportion. As the ſine of the angle oppoſite to the given ſide, to the ſide given; ſo is the ſine of the angle oppoſite to the required ſide, to the ſide required.

N. B. When an obtuſe angle is given, you muſt work by its complement to 180 degrees.

To work this Caſe upon the ſectoral lines,

From the centre of the lines of lines, take the length of the given ſide B C 54 laterally between your compaſſes; which extent ſet off as a parallel betwixt 35° 30′, and 35° 30′, the ſine of its oppoſite angle A, upon the lines of ſines: the ſector thus opened, take between your compaſſes the parallel diſtance between 44° 15′, and 44° 15′, the quantity of the angle B, upon the lines of ſines; and

and applying the ſaid diſtance laterally upon either of the lines of lines, it will give 65 for the length of the oppoſite ſide A C. So likewiſe the parallel diſtance between 79° 45′, and 79° 45′, (the complement of 100° 15′, the quantity of the angle C) will, when applied laterally on either of the lines of lines, give 92 for the length of the ſide A B.

Upon the artificial lines,

Set one foot of your compaſſes on the lines of ſines in 35° 30′, the quantity of the angle A, oppoſite to the given ſide B C, and extend the other to 44° 15′, the quantity of the angle B; the ſame extent will reach upon the line of numbers from 54, the length of the given ſide BC, to 65, the length of the required ſide A C. Or ſetting the firſt foot as before in 35° 30′ on the ſines, extend the other to 79° 45′ (the complement of 100° 15′ to 180°); the ſame extent will reach on the line of numbers, from 54 to 92, the length of the oppoſite ſide A B.

CASE III.

Two ſides, and an angle oppoſite to one of them being given, to find the other ſide.

As, ſuppoſe in the foregoing triangle, the ſide AC being 65 leagues, and the ſide BC 54 leagues,

and

and the angle A, oppoſite to the ſide BC, 35° 30′, it were required to find the ſide AB.

To work this Caſe either upon the ſectoral or artificial lines.

1. Find the angles, by Caſe the firſt.

2. The ſide, by Caſe the ſecond.

CASES IV. and V.

Two ſides and the contained angle being given, to find the other two oppoſite angles, and the other ſide.

As, ſuppoſe in the foregoing triangle, the ſide AC, as before, 65 leagues, and the ſide AB 92 leagues, and the contained angle A 35° 30′, it were required to find the other oppoſite angles B and C, with the ſide BC.

The proportion for finding the angles in this caſe is as follows: *viz.* As the ſum of the two ſides AC and AB, to their difference, ſo is the tangent of half the ſum of the angles B and C, *viz.* 72° 15′, to the tangent of half their difference; which, added to their half ſum, gives the greater angle C; but ſubtracted from the ſaid half ſum, leaves the leſſer angle B.

N. B.

N. B. The ſum of the angles B and C is found by ſubtracting the given angle A, *viz.* 35° 30′, from 180°.

To work theſe Caſes upon the ſectoral lines,

Theſe two caſes are taken together, becauſe upon the ſectoral lines it is neceſſary to find the length of the third ſide, before the angles can be diſcovered. To find therefore the length of the ſide B C, take the quantity of the given angle A 35° 30′, laterally upon one of the lines of ſines, and ſet it off as a parallel betwixt 90 and 90, on the ſaid lines: The ſector thus opened, ſet one foot of your compaſſes in 92, the extent of the ſide A B, upon one of the lines of lines; and extend the other to 65, the length of the other given ſide A C, upon the other line of lines; this extent meaſured laterally from the centre, upon either of the lines of lines, will give 54 for the length of the required ſide B C: Then may the quantity of either of the required angles be found by *Caſe* the firſt; which, added to the given angle, and the ſum ſubtracted from 180, will give the quantity of the other angle.

Upon the artificial lines,

Firſt, to find the angles: Set one foot of your compaſſes upon the line of numbers in 157, (the ſum of the ſides A B and A C) and extend the other backwards to 27 (the difference of the ſides);

ſides); the ſame extent will reach on the line of tangents from 72° 15′ (half the ſum of the angles B and C) to 28°; which, added to 72° 15′, gives 100° 15′ for the greater angle C; or, ſubtracted from 72° 15′, leaves 44° 15′, the leſſer angle B. The angles thus found, the ſide B C may be obtained by *Caſe* 2.

CASE VI.

The three ſides being given, to find the angles.

As, ſuppoſe in the foregoing triangle, the ſide A B 92 leagues, the ſide A C 65 leagues, and the ſide B C 54 leagues.

To work this Caſe upon the ſectoral lines,

Firſt, fixing upon any one angle, as ſuppoſe the angle A, note the extent of the two ſides which include it, *viz.* A B 92, and A C 65; then taking the extent of the third ſide B C 54 between your compaſſes, ſet one foot in 92, upon one of the lines of lines, and open the ſector, till the other foot falls upon 65, on the other line of lines: The ſector thus opened, take betwixt your compaſſes either the parallel diſtance between 30 and 30 in the ſines; which meaſured laterally from the centre on either of the lines of ſines, will give 17° 45′, half the quantity of the angle ſought: or take the parallel radius, *viz.* the extent betwixt 60 and

and 60 on the chords; which, meaſured laterally on either of the lines of chords, will give you the whole quantity of the required angle A, *viz.* 35° 30′. The angle B may either be found by the ſame method, from the three given ſides, or by the help of the diſcover'd angle A, according to the method laid down in *Caſe* 1.

The two angles A and B thus found, ſubſtract their ſum from 180°, the remainder will be the quantity of the third angle C.

Upon the artificial lines,

To work this caſe upon the artificial lines, firſt divide the baſe, or longeſt ſide A B, into two ſegments, by a perpendicular let fall from the oppoſite angle C; the value of which ſegments are diſcoverable by the following proportion, *viz.* As the true baſe to the ſum of the other two ſides, ſo is the difference of the ſaid two ſides to the difference of the ſegments of the baſe; which difference, added to the true baſe, will give the double of the greater ſegment; but ſubſtracted, will leave the double of the leſſer ſegment.

Set therefore one foot of your compaſſes on the line of numbers in 92, the length of the true baſe, and extend the other to 119, the ſum of the two other ſides; the ſame extent will reach on the ſame line, from 11, the difference of the ſides, to

14, 228, the difference of the ſegments of the baſe; which difference 14, 228, added to the true baſe 92, gives 106, 228, the double of the greater ſegment; but ſubſtracted, leaves 77, 772, the double of the leſſer ſegment.

The triangle therefore being divided into two rectangled triangles, by the perpendicular, and the ſegments of the baſe thus found, the angles may be obtained by *Caſe* the 6th of rectangled plain triangles.

I have now, I preſume, pretty well exemplified the uſes of the ſeveral lines laid down upon the modern ſectors; tho', beſides what I have mentioned, they are capable of very various applications, in menſuration, architecture, dialling, aſtronomy, *&c.* But as ſome ſectors, particularly the *French* ones, are furniſhed with lines of *Superficies*, and *Solids*; before I conclude, I will juſt give the manner of their projection, and application.

Pro-

Projection of the lines of Superficies.

Let the lines A E A E repreſent the lines of ſuperficies; to divide which, having a ſcale of 1000 equal parts of the ſame length as the intended lines, take therefrom 125 parts; which ſet off from the centre A, as the firſt diviſion upon each: 250 parts will give you the fourth diviſion; the mean proportion between 125 and 150, will be the number of parts marking the ſecond diviſion; 375 parts taken from the ſcale, and ſet off from the centre A, will reach to the ninth diviſion; the third diviſion will be the mean proportion between 125 and 375. Again, 625 parts will give the 25th diviſion; and the mean proportion between 125 and 625, will be the fifth diviſion, *&c.* laſtly, 1000 parts will be the 64th diviſion: All which is plain from the conſideration, that ſimilar ſurfaces are in a duplicate ratio of their homologous ſides.

Fig. 17.

Uſe of the line of ſuperficies.

Taking between the points of your compaſſes the radius of a circle, or the ſide of any plain figure, and ſetting it as a parallel betwixt 1 and 1, the firſt diviſion from the centre; ſo ſhall the

parallel extent betwixt 2 and 2, give you the radius of a circle, or ſide of a figure of a double area; and betwixt 3 and 3 triple, &c.

In the ſame manner may be found circles, and other plain figures ſubdouble, ſubtriple, &c.

Projection of the lines of ſolids.

Let the lines A F A F repreſent the lines of ſolids: From the ſaid ſcale of 1000 equal parts, ſet off from the centre A 250, for the firſt diviſion, and 500 for the 8th; then finding two mean proportionals betwixt 250 and 500, the firſt will give you the ſecond diviſion; and the ſecond the fourth: To find this firſt mean proportional, ſubſtract the logarithm of 250 from the logarithm of 500, and adding the $\frac{1}{3}$ of what remains to the logarithm of 250, you will get the logarithm of the firſt mean proportional; which will be nearly 315: and if you add again the ſame $\frac{1}{3}$ to the logarithm of 315, you will have the ſecond mean proportional. For the third diviſion, take the firſt of two mean proportionals between 250, and the triple thereof, 750; and for the fifth diviſion, take the firſt of two mean proportionals between 250 and 1250, five times 250, &c. Laſtly, the whole line A G, or a H, being 1000 equal parts, will be the 64th diviſion.

Uſe

Uſe of the line of ſolids.

Set over the ſide of any body, as a parallel betwixt 1 and 1, the firſt diviſion on the lines of ſolids; and the parallel extent betwixt 2 and 2, ſhall give the homologous ſide of a ſimilar body, whoſe ſolid content ſhall be double; and ſo the ſeveral other diviſions will accordingly give ſides of bodies triple, quadruple, *&c.* or ſub-double, ſub-triple, ſub-quadruple, *&c.*

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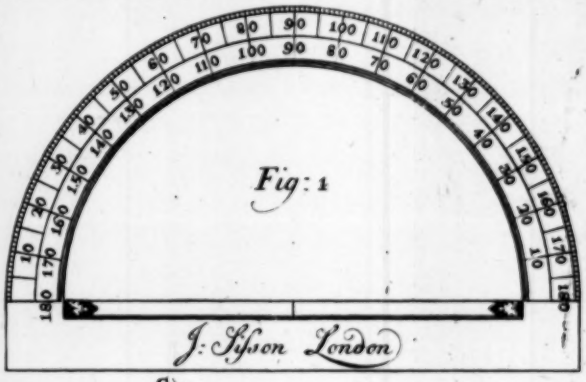
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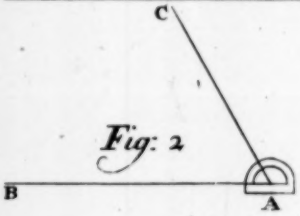
C
Fig: 2
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Fig: 4
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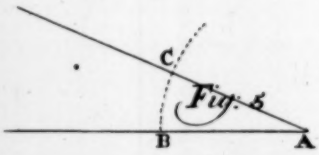
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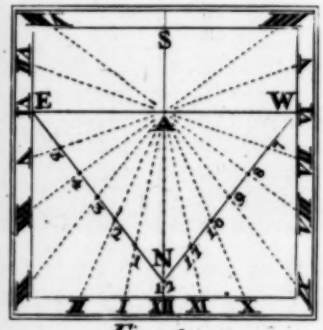
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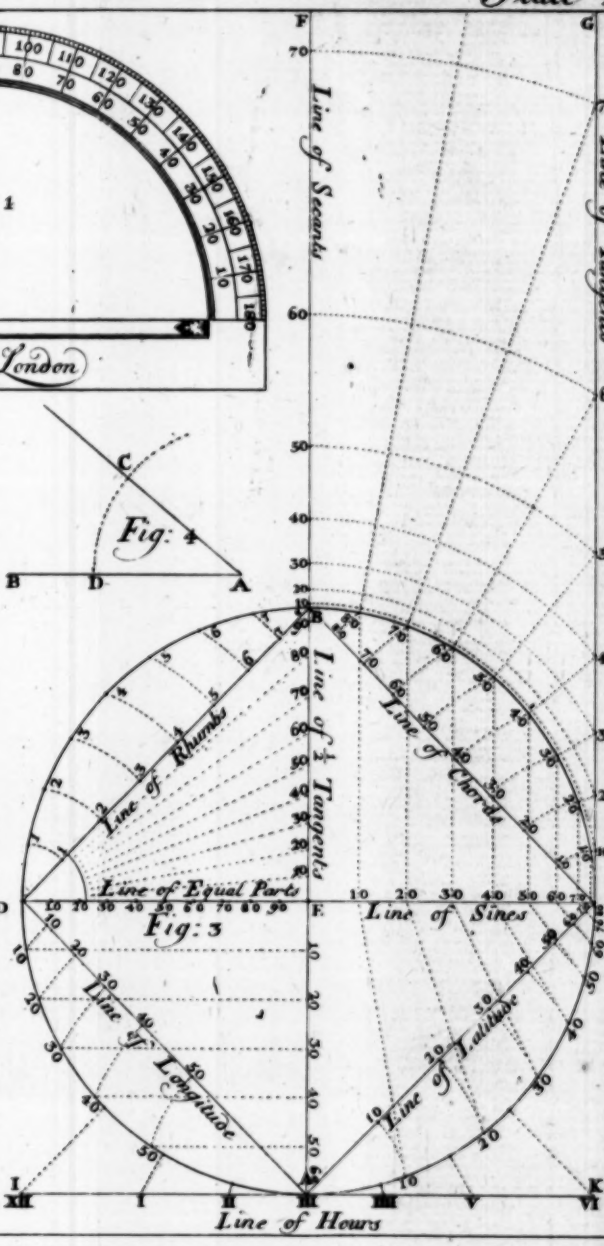
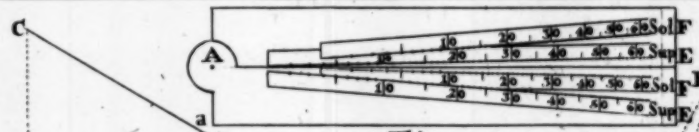

Line of Secants
Line of Tangents
Line of ½ Tangents
Line of Rhumbs
Line of Chords
Line of Equal Parts
Line of Sines
Line of Longitude
Line of Latitude
Line of Hours
Fig: 3



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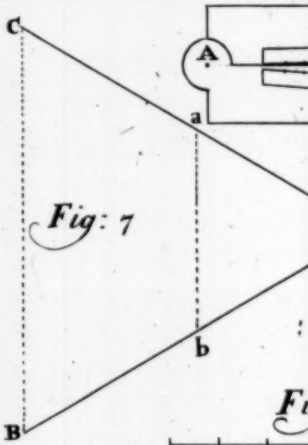

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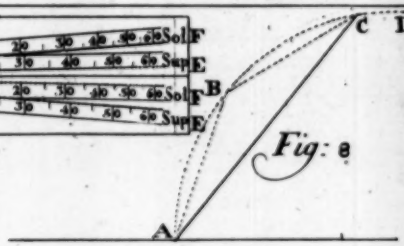

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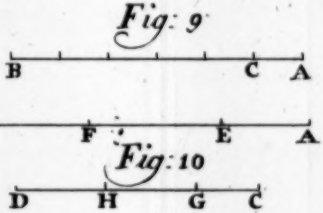

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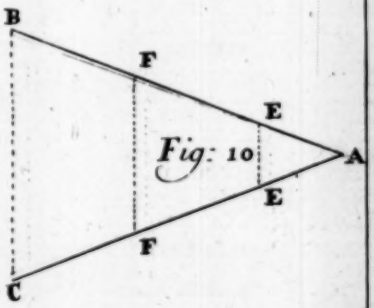

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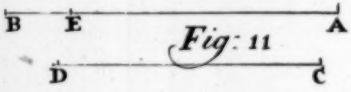

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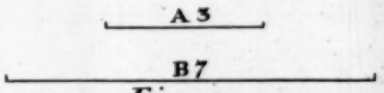

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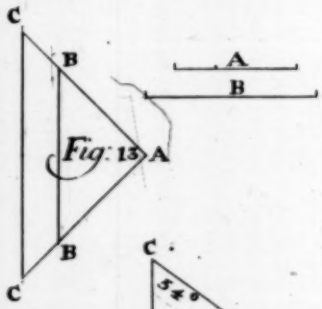

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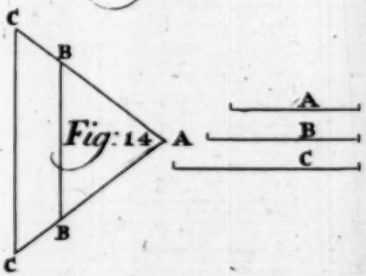

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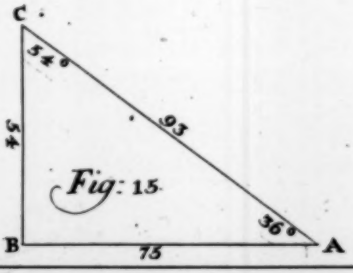

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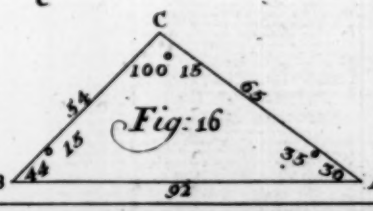

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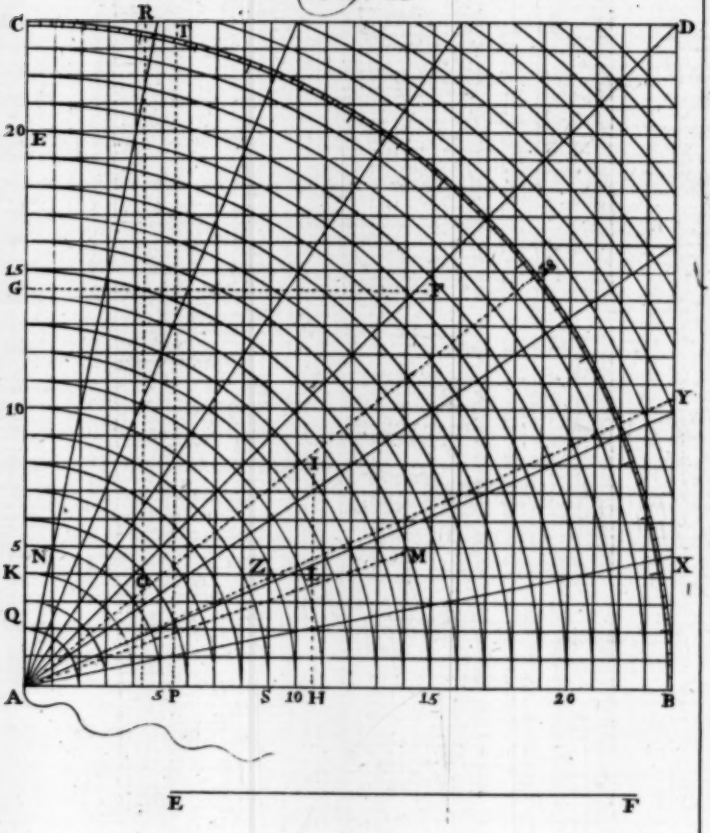

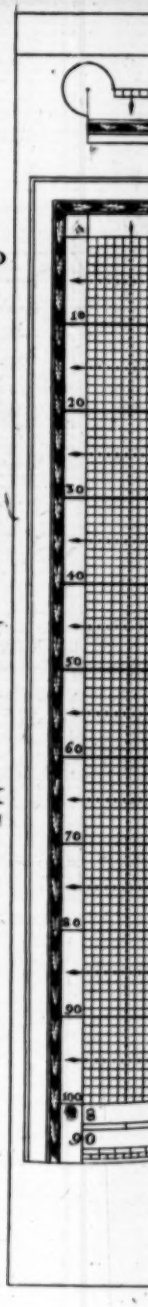

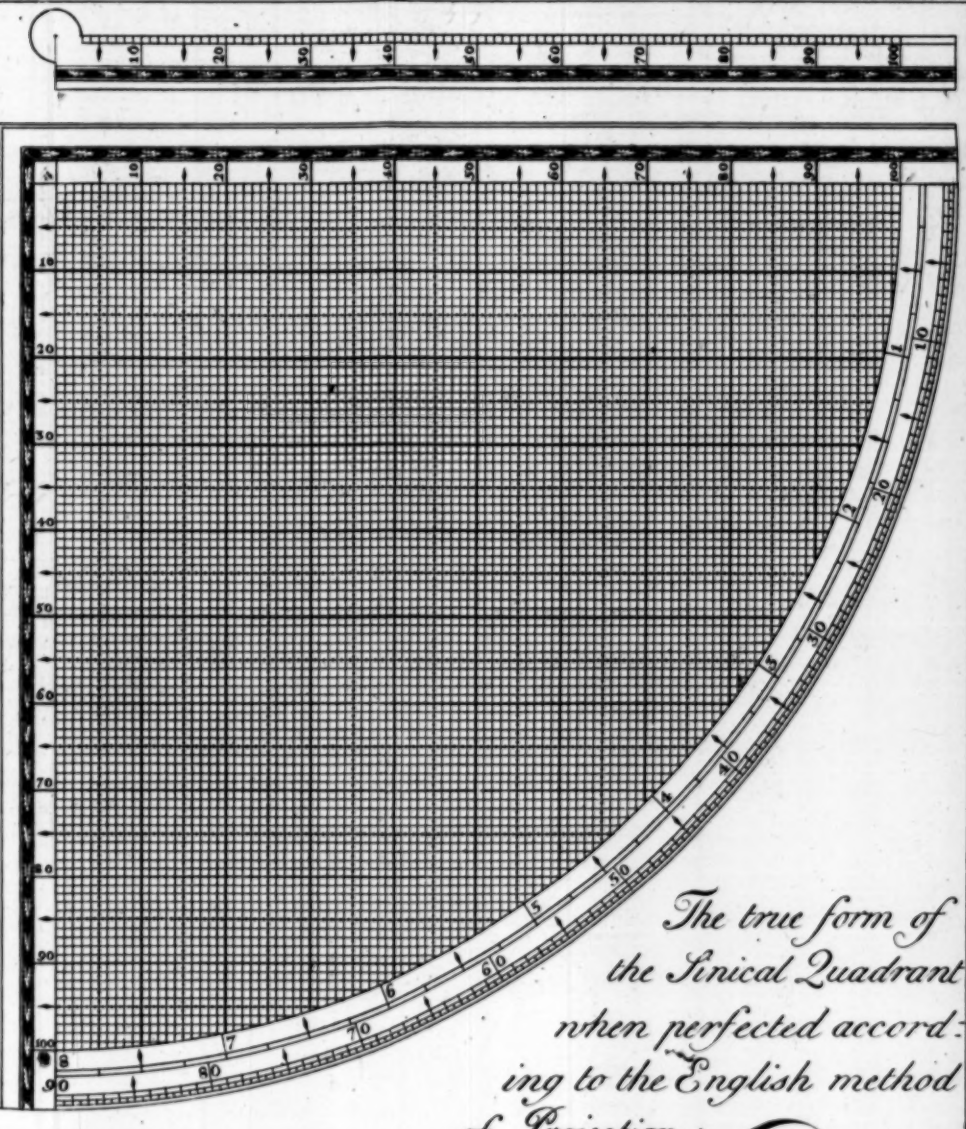

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